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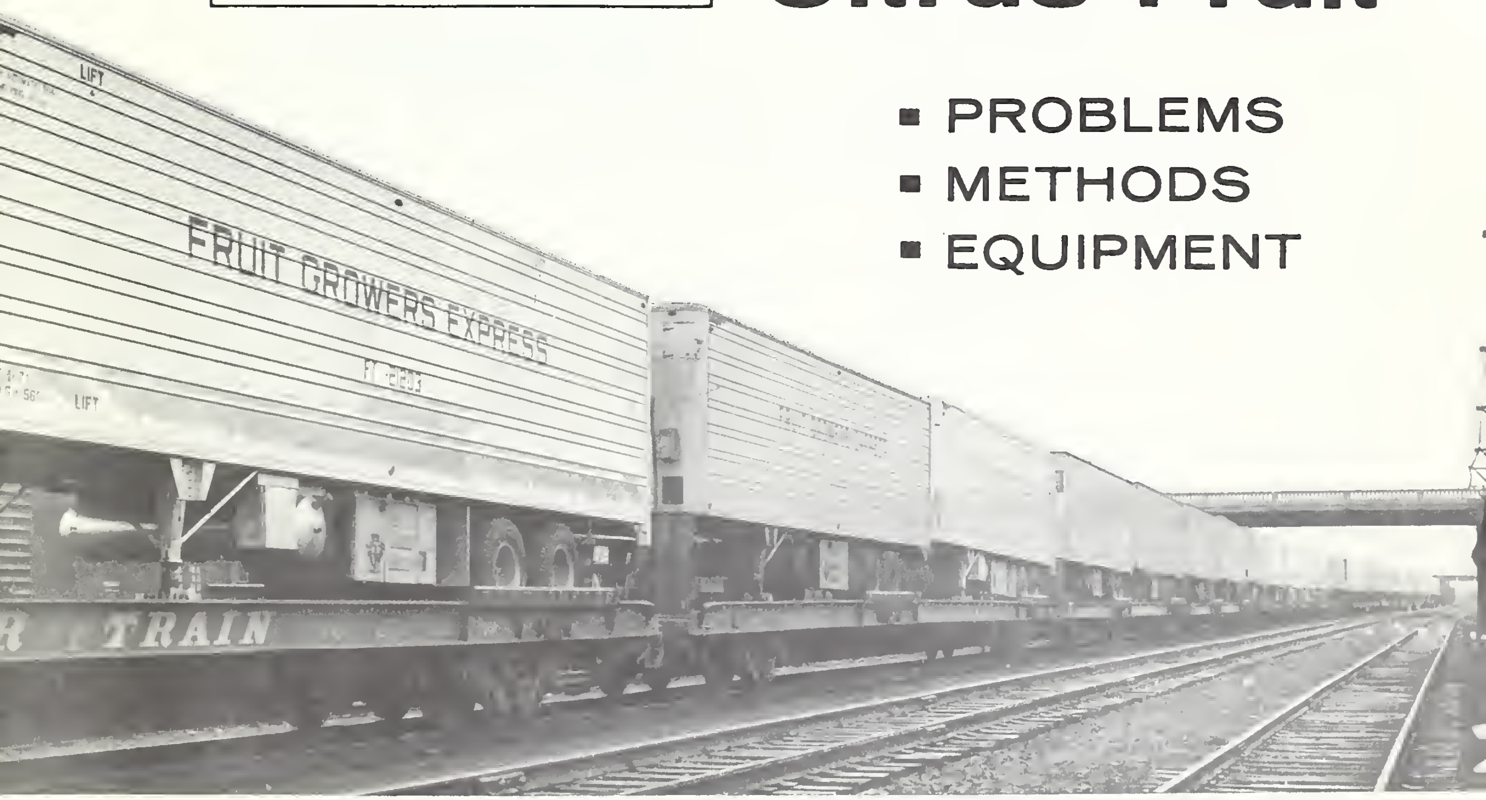
PIGGYBACK TRANSPORTATION of Florida Citrus Fruit

AN INTERIM REPORT

- PROBLEMS
- METHODS
- EQUIPMENT



U.S. DEPARTMENT OF AGRICULTURE - AGRICULTURAL MARKETING SERVICE

TRANSPORTATION AND FACILITIES RESEARCH DIVISION
AND MARKET QUALITY RESEARCH DIVISION

PREFACE

The purpose of the study on which this report is based was to solve some of the problems which developed in the initiation of rail piggyback service for the Florida citrus industry in the 1960-61 shipping season, thereby improving efficiency in marketing.

The results presented in this interim report are based on only one year's study. They are presented now to alert shippers and carriers to some of the problems in rail piggyback service revealed thus far, and to suggest some solutions that may be employed immediately, before completion of this study.

The research was conducted jointly by the Transportation Research Branch of the Transportation and Facilities Research Division and the Horticultural Crops Branch of the Market Quality Research Division, Agricultural Marketing Service, U. S. Department of Agriculture.

Cooperation by many individuals and companies made this study possible. The Fruit Growers Express Company and the Seaboard Air Line, Atlantic Coast Line, and Florida East Coast railroads originated the test shipments. Isleworth Groves, Nevins Fruit Company, and the Florida Citrus Exchange supplied the shipments of fruit.

The following personnel of the Agricultural Marketing Service also participated in the study: Thomas H. Camp, William F. Goddard, Robert F. Guilfoy, David W. Kuenzli, and Kenneth Myers, of the Transportation and Facilities Research Division; and Randall H. Cubbedge, of the Market Quality Research Division.

CONTENTS

Washington, D. C. July 1962

SUMMARY AND RECOMMENDATIONS

During the 1960-61 shipping season, rail piggyback service was offered to Florida citrus shippers on a limited, experimental basis. Shipper response to the service was good, and available equipment was used intensively. This interim report presents the results of preliminary research conducted to evaluate certain aspects of this service and to develop solutions to some of the problems encountered by carriers and shippers in adapting the new equipment and service to their operations.

The trailers used for this service were from different manufacturers, and, although they differed slightly in some design details, all were heavily insulated and equipped with ceiling ducts, sidewall ribbing, and high-capacity mechanical refrigeration units. Almost all of the desirable modifications tested in the interior equipment, such as covering the screened opening in the front bulkhead, have been incorporated in some of the existing vehicles and in all new equipment recently acquired for this service.

Piggyback trailers are placed on rail flatcars, facing either forward or backward in relation to the direction of train movement. It was found that when the trailers were transported with the front ventilation openings facing forward, there was a much greater and more constant supply of incoming air for ventilation than when the vehicles moved with the rear ventilation openings forward.

When the screened upper half of the front bulkhead in an unmodified trailer was left open, incoming air in ventilated shipments and circulating air in refrigerated loads moved over the top of the load, bypassing the main body of the load and resulting in a low rate of cooling. However, when the screened opening was closed, air circulation and cooling around the perimeter of the load was considerably increased, but air movement through channels in the load was only slightly improved. A modification of the loading pattern, which provided 84 openings in the top layer, permitted the circulating cooled air in refrigerated shipments to reach the channels in the load more easily, further improving the rate of cooling.

The fruit in all test shipments under refrigeration or ventilation service arrived at destination in good condition with little or no decay or rind breakdown. Further research to develop and appraise some additional innovations in loading patterns and equipment and the overall economic aspects of the new transportation service is continuing. The following recommendations, based on the results of this preliminary research, will enable carriers and shippers to derive greater benefits from piggyback service:

1. Ventilation of citrus shipments with outside air, which many shippers used instead of mechanical refrigeration during the cool months, will not provide effective cooling of the fruit unless the temperature of the outside air is between 30° and 40° F. If the shipper cannot be sure that the outside air temperature will be in this range during most of the trip, particularly during the first 24 hours, the shipment should be made under mechanical refrigeration.

2. The upper half of the bulkhead at the front of the trailer should have no openings except for the duct opening from the evaporator coils of the mechanical refrigeration unit, or a small door which permits access to the nose area for servicing. This forces the air to circulate around or through the load.

3. Loads shipped under refrigeration in trailers with sidewall stripping or ribbing should have a number of openings in the top layer, which permit the circulating air to reach the channels in the main body of the load.

4. During movement by rail, there is a good supply of air at relatively high velocities along the sides and tops of the trailers. Preliminary investigations show that some device such as an air scoop at these points will deflect more air for ventilation into the cargo area. More research should be done to determine the best design and location for the scoops, and their effectiveness in providing cooling under ventilation.

PIGGYBACK TRANSPORTATION OF FLORIDA CITRUS FRUIT

Problems - Methods - Equipment

- An Interim Report -

By Russell H. Hinds, Jr., and William G. Chace, Jr. 1/

INTRODUCTION

Trailer-on-flatcar or "piggyback" service was first offered to Florida shippers in the 1960-61 shipping season as a pilot operation for moving citrus and citrus products to Baltimore, Philadelphia, and New York. During the first season, 2,373 trailers of fresh fruit, 423 of chilled juice, and 30 of frozen concentrate moved by piggyback.

To provide adequate protection during transit for fresh, chilled, or frozen commodities, heavily insulated truck trailers with thermostatically controlled mechanical refrigeration units are used. Piggyback trailers equipped with ventilation hatches on the front and rear may also be shipped with ventilation service under certain weather conditions. The trailers are delivered over the highway to the shipper. Loaded trailers are assembled at the rail point and loaded on large, specially designed flatcars for transport north. Most piggyback trains are moved on fast schedules, reducing normal rail transit time by one or two days.

This kind of transportation service offers many advantages: (1) It combines the flexibility of truck transportation with the dependability of railroad service, (2) it permits moving heavier loaded trailers by rail across States having low gross weight limits for their highways, (3) it provides lower shipping costs in some instances, and (4) it is sometimes faster than over-the-road service. There also have been some disadvantages, such as the limited number of refrigerated piggyback trailers available, no multipoint unloading service, limited loading and unloading centers, and relatively poor pickup and delivery services in some areas. Some of these disadvantages have since been overcome in whole or in part as the service has been greatly expanded and new equipment and facilities have been placed in service.

1/ Russell H. Hinds, Jr., transportation economist, Transportation and Facilities Research Division, Agricultural Marketing Service, and William G. Chace, Jr., horticulturist, Market Quality Research Division, Agricultural Marketing Service.

Most of the problems in piggyback operations studied in this research were not the result of inadequacy of the trailer and flatcar equipment, which was the latest and most modern available. They resulted instead from its use for protective services for which it was not primarily designed. Some problems which can be solved by both carriers and shippers stem from using the trailers under different conditions in loading and in transit than exist when similar equipment is used for over-the-road transportation.

Ventilation, refrigeration, equipment design, and loading patterns were studied to determine the ability of piggyback equipment to provide satisfactory shipping of fresh citrus under the particular conditions in which it was used. Rate of initial cooling, temperature maintenance during transit, air circulation, quality of fruit at destination, and subsequent shelf life were the criteria used to measure this ability under the varying conditions. Some modifications of the trailers that might increase their effectiveness for ventilation and refrigeration service also were studied.

EQUIPMENT AND METHODS

Trailer-on-Flatcar Citrus Tariff No. 910 2/

Railroad tariff No. 910 provides the rules and regulations for loading and unloading, protective services, pickup and delivery services at origins and destinations, and application of rates and services for piggyback shipments. Mechanical refrigeration is the only protective service specifically provided by this tariff.

No provisions had been made in this tariff at the time of this study for shipping citrus by piggyback under ventilation service as defined for rail cars in Rule 385 of the Perishable Protective Tariff. 3/ However, at the request of shippers, carriers did provide a ventilation service for piggyback shipments from Florida to northern markets during the 1960-61 season.

The charge for mechanical refrigeration at the time this study was made was $35 per trailer from points in Florida to northern markets. When the ventilation service was used in place of refrigeration at the shipper's request, there was no charge.

Description of Piggyback Equipment

Trailers.--A wide variety of trailer equipment is offered by railroads servicing the Florida citrus shipping areas. Trailers of six manufacturers and two makes of refrigeration units were in service at the time of this study.

2/ Southern Freight Tariff Bureau; Trailer-on-Flatcar Citrus Tariff No. 910, ICC No. 5-149. Agent, C. A. Spaniger.

3/ Perishable Protective Tariff No. 18, ICC No. 34, National Perishable Freight Committee. Agent, W. T. Jamison.

All initial equipment used in this study, provided by the railroads, had the following specifications:

The trailers were 40 feet long, with a loading space of about 1,700 to 1,800 cubic feet. Each trailer was equipped with at least 6 inches of insulation in walls, floor, and ceiling, and was cooled by a $7\frac{1}{2}$-ton-capacity refrigeration unit. The floors were grooved aluminum extrusions and the sidewalls were stripped. Cold air distribution ducts were attached to the ceiling and extended from the blower outlet to the rear of the cargo area. Removable load braces (fig. 1) were used to protect the rear doors from damage by backward shifting of the load.

The trailers were equipped with two ventilation doors high on the front corner of each van and two in the large rear doors. The purpose was to permit cool outside air to enter the trailers from either end, since they move either forward or backward during rail transit. Air entering the trailer passes over, around, and through the load, when it is cool, removes field heat and reduces commodity temperature.

Some of these physical features varied between units, since the trailers were not all built by the same manufacturer. The size and location of both front and rear ventilation doors were not uniform, resulting in irregular performance when the various trailers were operated under ventilation (fig. 2).

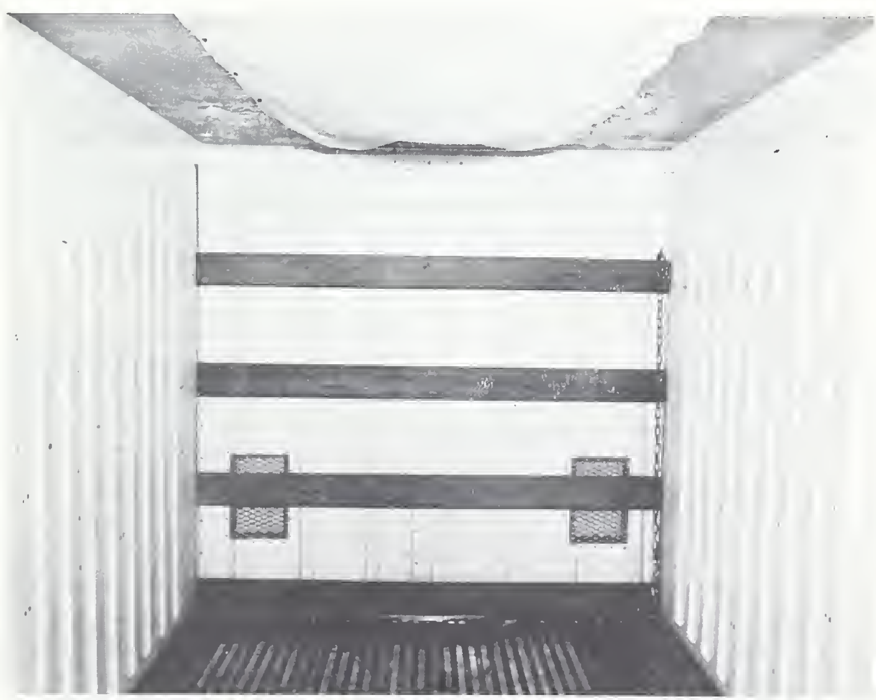


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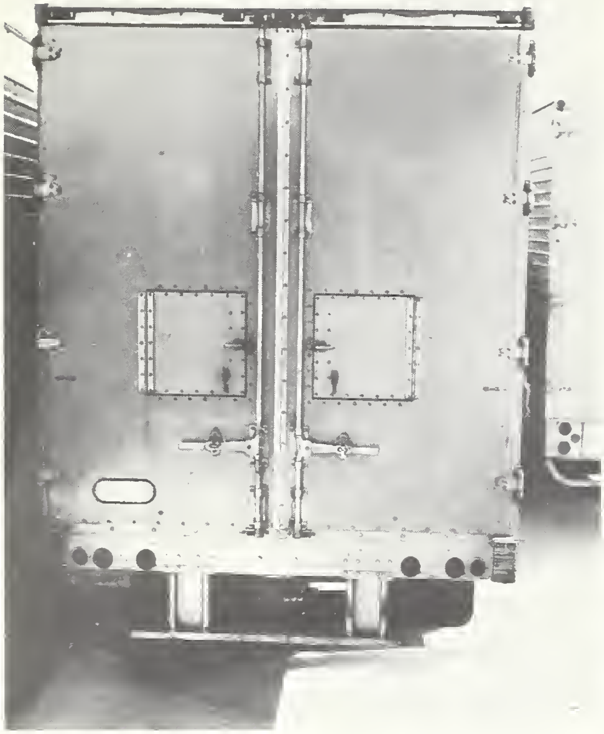
Figure 1.--Interior of piggyback trailer looking toward rear doors. Note removable load braces.



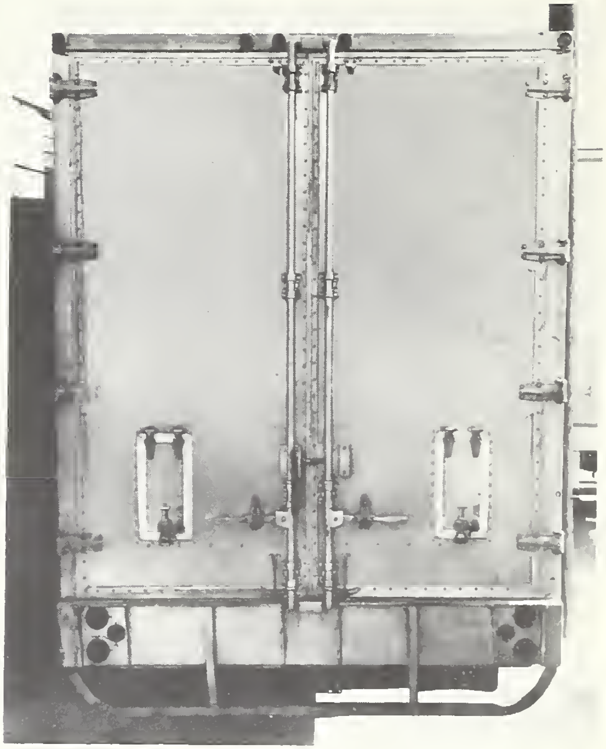


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Figure 2.--Rear view of two types of piggyback trailers. Note differences in size and location of door vents. Of the type shown on the right, only 16 were in service at the time this study was made. All newer units recently placed in service have large ventilation doors near the sidewalls of the trailer.

In addition, three types of fabric ceiling ducts were employed for cold air distribution when the trailers were operated under refrigeration (fig. 3). The first type was a side-vented duct which extended from the blower opening to within about 4 feet of the rear doors. The sides of the duct were loosely suspended from hooks in the ceiling which allowed part of the cold air to escape and spill downward over the load on either side along its entire length. The second type had the sides of the duct tightly attached to the ceiling, preventing the cold air from escaping before it reached the opening at the rear of the duct. The third type was the so-called finger duct, which was installed in trailers equipped with meat rails and which was composed of six small U-shaped ducts of varying lengths. These were tightly attached to the ceiling, so that all the cold air was forced out the ends of the six ducts. Two of the ducts discharged the air in the front third of the trailer, two in the middle third, and the last two in the rear third, providing uniform air distribution throughout the vehicles.

The mechanical refrigeration units of two manufacturers installed on these trailers were similar in design and capacity.

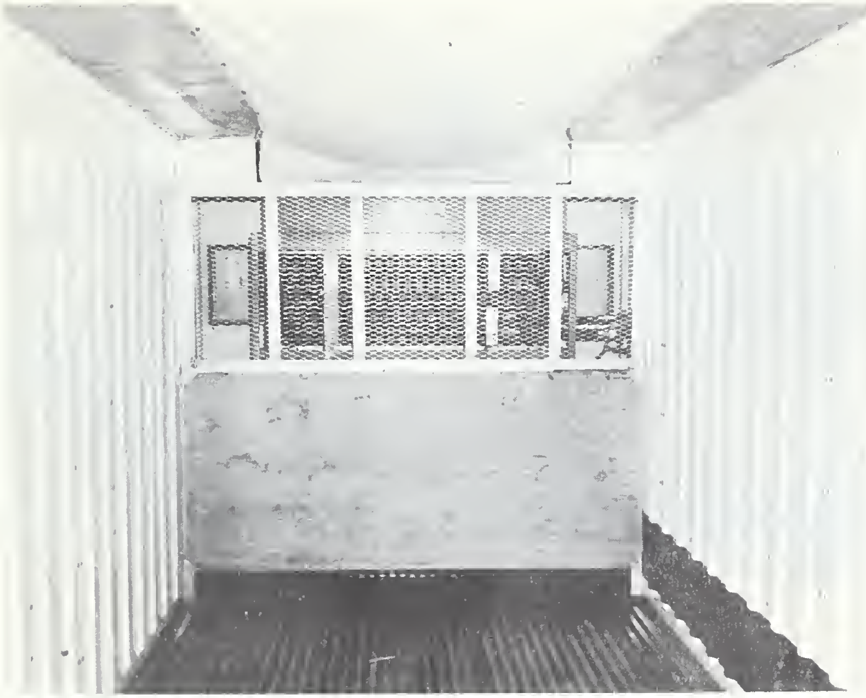

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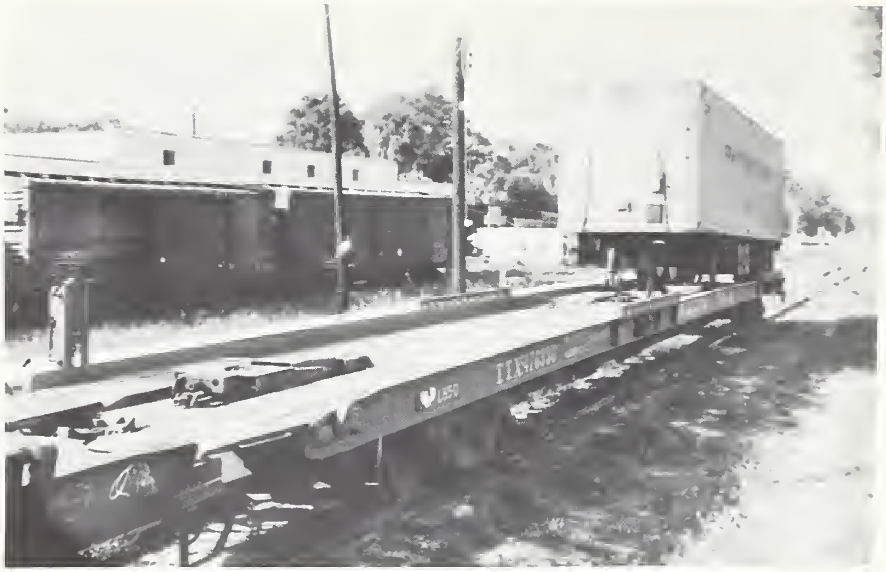
Figure 3.--Interior of piggyback trailer, looking toward front bulkhead.

A bulkhead at the front of the trailer shown in figure 3 was approximately 18 inches from the front wall. The upper part was made of expanded metal screen and the lower part of plywood with an 8-inch-high open space across the bottom. This bulkhead provided protection from physical damage to the refrigeration coil, and permitted easier front-end loading by eliminating the irregular space in the nose of the trailer caused by rounded corners and the refrigeration unit.

Rail flatcar.--A special type of rail flatcar used for the piggyback service was 85 feet long and accommodated two 40-foot trailers. Each was equipped with tiedown devices to hold the trailers in place during rail transit (figs. 4-A and 4-B).

The cars were equipped also with high-capacity roller bearings and long-travel spring-equipped stabilized car trucks, to facilitate smooth, high-speed operation.

To load trailers at the railhead, the flatcars were placed in a string on a rail siding equipped with either an inclined loading ramp or a loading platform at one end, with its deck at the same level as the flatcars. Hinged bridge plates on diagonally opposite corners of each flatcar bridged the space between adjoining cars when the plates were lowered into position. With the bridge plates lowered, the trailers were backed over one flatcar and on to another so that the flatcars were loaded in a string, beginning with the car



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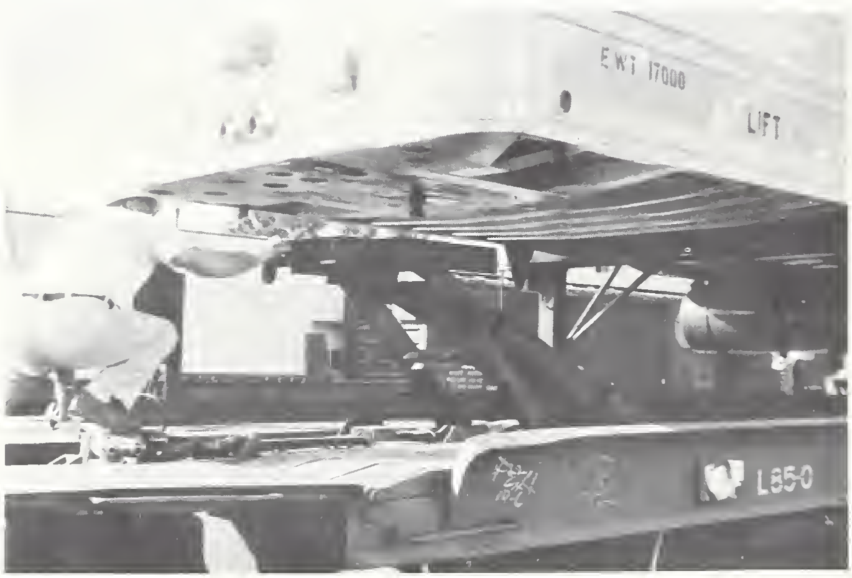

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Figure 4.--A. Specially designed 85-foot piggyback flatcar with retractable trailer hitches designed to accommodate two 40-foot trailers. Tie-down device or trailer hitch is shown in lowered position on deck of flatcar. One of the hinged bridge plates which spans the gap between the flatcar in the center of the picture and the adjacent flatcar at the lower left is shown in lowered position. B. Piggyback trailer loaded on flatcar. Man at left is raising trailer hitch into position to support and secure front of trailer during rail transportation.

farthest from the loading ramp at the end of the track and ending with the one adjacent to the ramp. The trailers were backed onto the flatcar by an over-the-highway tractor, and firmly secured to the flatcar by tiedown equipment (fig. 4-B). At destination, the unloading process was reversed. When the trailers arrived at the unloading ramp facing the wrong direction for unloading, either the flatcars were turned around by switching so the trailers could be pulled, nose end first, off the car or large gantry cranes were used to lift the trailers from the cars to the ground.

The highway tractors used for pickup and delivery of the trailers were lightweight cut-down tractors which complied with local State laws governing overall trailer-tractor weight and length. Since most of the trips from the packinghouse to the loading ramp were relatively short, some tractor equipment and accessories required for long-distance over-the-highway tractor movement were eliminated. In most instances, the railroads hired local truckers to load and unload the piggyback trailers on a per-unit basis.

Air Velocity Measurements

Air velocity measurements were taken inside the trailers as they were transported, under both refrigeration and ventilation services. The rates of airflow at given points within the trailer were used as indications of the effectiveness of loading patterns and interior trailer designs on product cooling and maintenance of in-transit temperatures.

Both a vane, or windmill, type of anemometer and a hot-wire type were used to obtain air velocity data. A remote reading adapter was used with the hot-wire anemometer, which made it possible to obtain air velocity measurements in small, hard-to-reach circulation passageways throughout the trailer.

Direct observations of the path of air movement within the trailer and through the load were made with a smoke gun. Smoke movement afforded a quick, reliable method of determining general flow patterns in a closed circuit, and pinpointed the areas in which air movement should be measured with anemometers.

Temperature Measurements

Temperature data developed in this study were used to determine the ability of the units to provide initial cooling of warm fruit and to maintain desirable in-transit temperatures. The effects of certain loading patterns, of modifications of some interior features of the trailers, and of air circulation on product temperatures also were investigated. Temperature changes were used as the criteria by which the effects of each innovation were measured.

Thermocouples used in conjunction with recording potentiometers and recording thermometers were the primary instruments used in gathering temperature data in both accompanied and unaccompanied transit tests, although recording and stick thermometers also were employed. In a stationary 48-hour test, thermocouple cables were run from the trailer to a multipoint recording potentiometer in an adjoining building. For unaccompanied over-the-rail tests,

recording thermometers and a similar battery-powered recording potentiometer, installed in the trailer, were used for recording in-transit temperatures. A manually operated portable unit also was used in some of the tests.

Loading Patterns

Use of a stable loading pattern permitting circulation of cool air through the load from the refrigeration unit is necessary if the full benefit of modern refrigeration equipment is to be realized. Use of loading patterns which do not provide these conditions can nullify to a large extent the advantages of shipping the product in a modern trailer with adequate refrigeration facilities.

A complete study of loading patterns for different containers for Florida oranges and grapefruit was under way at the time this study was made. A new loading pattern for full-telescope corrugated fiberboard boxes of fruit in truck trailers, developed in the initial phase of the loading research, had been adopted and was in general use by citrus shippers.

In this study, the adequacy of the new loading pattern in facilitating circulation of air through the loads to provide effective cooling was evaluated. Modifications of the pattern that might result in improved air circulation and improved cooling of the load also were studied.

RESULTS

Ventilation Service

During the cool months, many citrus shippers prefer to use outside air for cooling the fruit in transit by shipping the load under ventilation. However, ventilation will not cool the load effectively unless the following conditions are met: (1) The temperature of the outside air must be sufficiently low (preferably between 30° and 40° F.), (2) there must be an adequate supply of outside air entering and leaving the vehicle, and (3) the containers must be loaded in such a way that incoming air will move through channels between the containers. If the shipper cannot be reasonably sure that outside air temperatures will be low enough to provide sufficient cooling, the shipment should be made under refrigeration.

Factors influencing airflow.--With the nose of the trailer facing forward on the flatcar, outside air could readily enter the front vents, which are located high and on the outside corners of the trailers. When trailers are loaded on the flatcar so that the rear end faces forward in transit, air movement into the trailer was restricted because the ventilation openings in the rear doors were located low and toward the center of the back of the trailer (fig. 2). In either case, the amount of air entering the trailer was dependent upon the speed of the train. At low speeds, air moving along the side of the train tended to curve into the opening between trailers and enter the vents. As the train speed increased, however, the air moved in a straight line along the sides of the trailers, with only limited amounts coming in between adjacent trailers to enter the rear ventilation openings when the trailer faced backward.

During movement by rail, a good supply of air is available along the sides and tops of the trailers. Preliminary investigations show an air scoop at these points could divert air into the cargo area. A more thorough study will be made to determine the practicability of scoops.

Piggyback trailers resemble conventional highway units in their basic design. However, the major part of their travel is similar to that of a conventional rail car rather than a trailer hauled over the highway. Each mode of travel provides a separate set of operating conditions that affect the efficiency of ventilation service. In highway movement, the trailers always move with the front end forward, and most of them are from 3 to 6 feet behind the tractor cabs. Moreover, the tops of the tractor cabs are generally several feet lower than the tops of the trailers. Under these conditions, plenty of outside air can readily enter the front vents. The same unit placed on a flatcar is about 35 inches from its companion trailer on the same car and about 72 inches from trailers on the adjoining cars. This close spacing of trailers in the trains restricts the amount of outside air that can enter the ventilation openings. In piggyback service, the trailers may move in a forward or backward direction, depending on the arrangement of the loading ramp and the switching done in making up the trains.

Factors influencing air distribution.--The bulkheads in the trailers studied (fig. 3) were constructed to allow most of the outside air entering the front ventilation openings to pass through the wire mesh in the top half of the bulkheads, across the top of the loads, and out through the rear ventilation openings (fig. 5-A). The moving air followed the path of least resistance, resulting in slow cooling for a load of hot citrus except in the cartons in the top layer and rear stack.

Some changes in bulkhead design were tried in order to direct the incoming air into the longitudinal channels of the loading pattern normally used. This pattern 4/ consisted of alternate layers and stacks of boxes placed lengthwise and crosswise in the truck in such a way as to form a network of connecting air channels throughout the length of the load (fig. 6).

Measurements of air velocities in the trailers under ventilation service with blocked and unblocked bunker bulkhead screens, one of which moved with its front end forward and the other rear end forward, are shown in table 1.

With the trailers moving forward, the incoming air, which varied with the speed of the train, ranged from 800 to 1,840 feet per minute. In trailers on the same train loaded to move rear end forward, air entered the rear ventilation openings at a much lower velocity, ranging from 496 to 650 feet per minute. However, this movement was erratic and occurred only at low train speeds, with most of the air entering one rear opening and going out the other instead of traveling through the length of the trailer. Only slight air movement over the top of the load was detected.

When the screened upper half of the bunker bulkhead was left open, practically all of the moving air passed over the top of the load, and very

4/ Hinds, Russell H., Jr., A Better Way to Load Citrus. Agricultural Marketing, Oct. 1960. U. S. Dept. Agr.

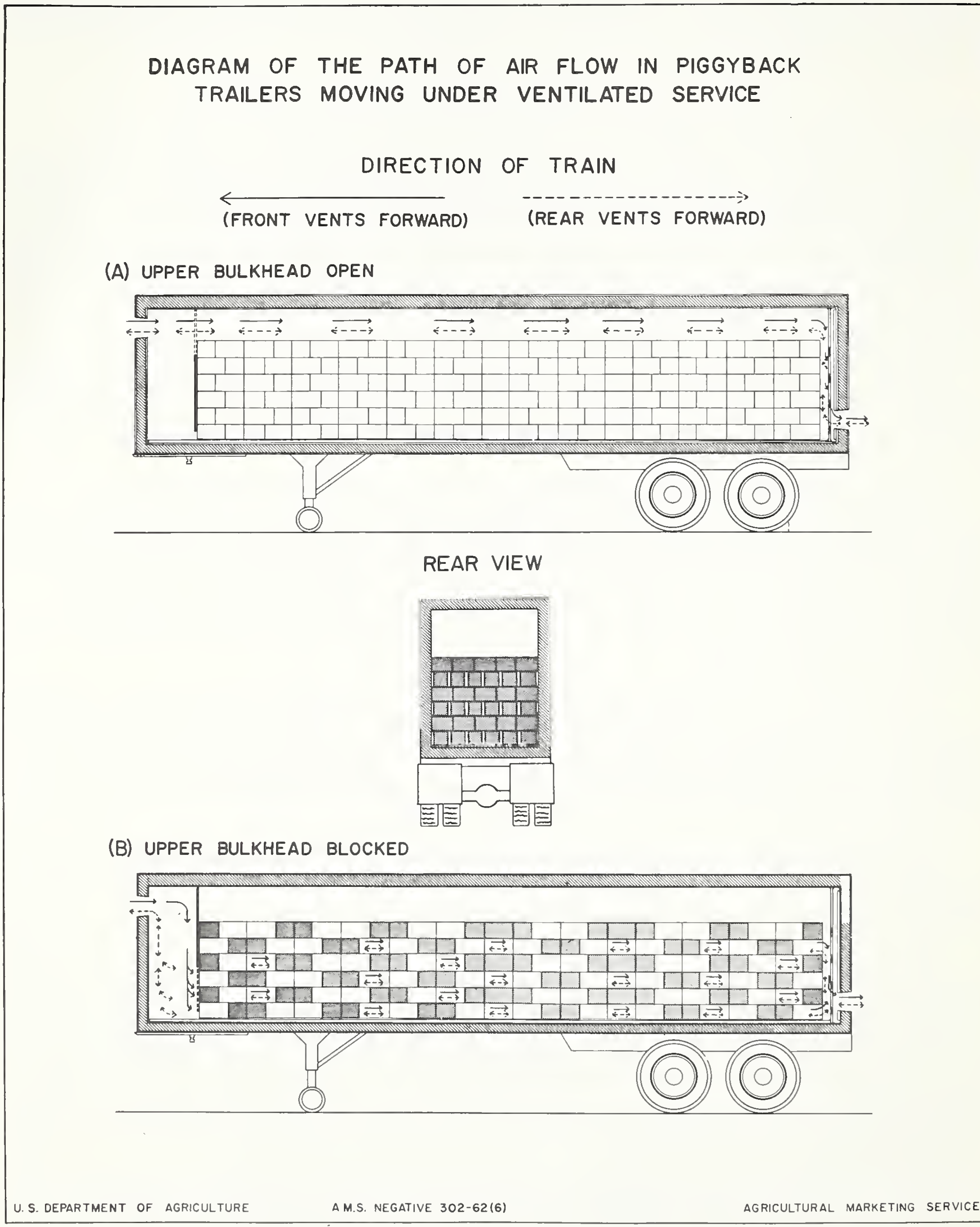
DIAGRAM OF THE PATH OF AIR FLOW IN PIGGYBACK TRAILERS MOVING UNDER VENTILATED SERVICE
DIRECTION OF TRAIN
(FRONT VENTS FORWARD)
(REAR VENTS FORWARD)
(A) UPPER BULKHEAD OPEN
REAR VIEW
(B) UPPER BULKHEAD BLOCKED
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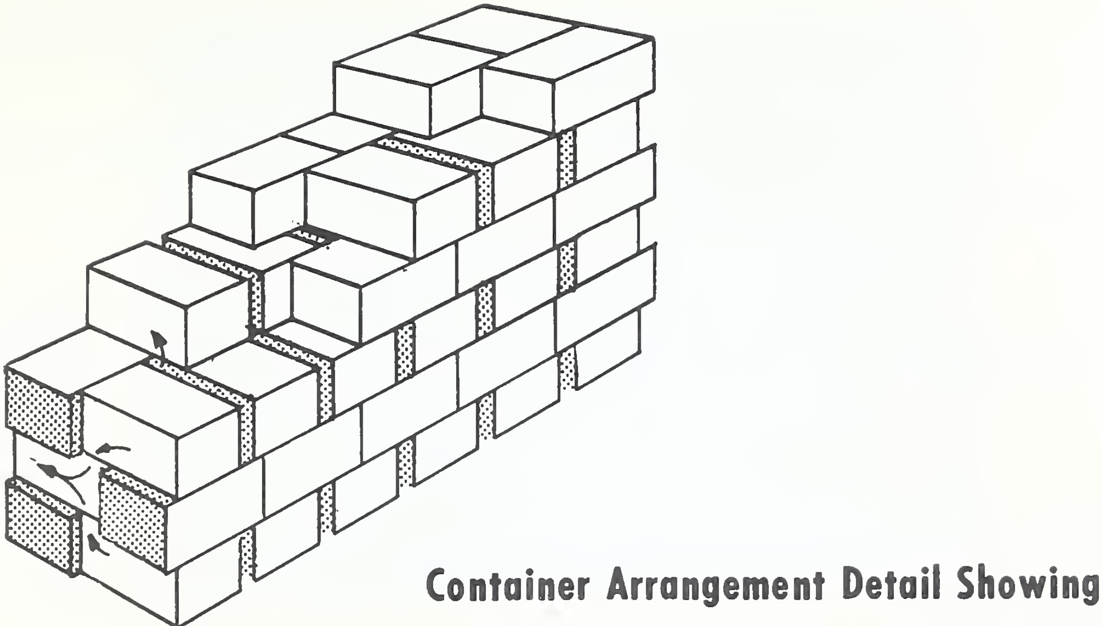
Figure 5.



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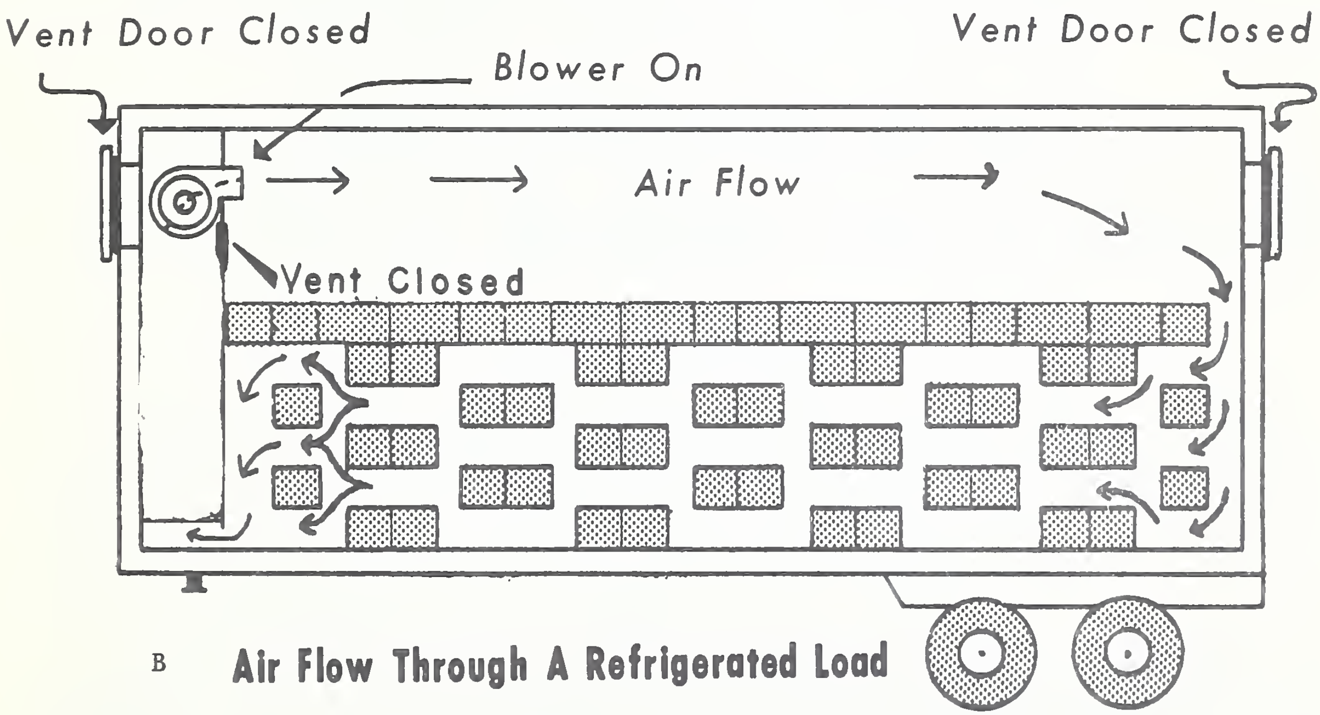

B Air Flow Through A Refrigerated Load

Figure 6.--A. Partly completed stack in bonded-block pattern. B. Network of air channels through pattern.

little air moved through the load channels. With the bulkhead screen blocked, however, the movement of air through the load was greatly increased, particularly in the trailer which moved front end forward.

Table 1.--Comparative air movement in piggyback trailers during tail transit under ventilation service, by position of trailer and bunker bulkhead screen arrangement

Position of airflow measurements	Air velocity			
	Screen open		Screen blocked	
	Trailer facing forward	Trailer facing backward	Trailer facing forward	Trailer facing backward
	Ft/min	Ft/min	Ft/min	Ft/min
Incoming (front or rear vent)..........	1,840	1/ 496	800	1/ 650
In channels of load...	Less than 5	Less than 5	185	125
Over top of load (middle of trailer)..	330	110	0	60

1/ Some of the incoming air moved in one rear vent and out the other rear vent.

Figure 7 shows a modified bulkhead in which the top screened opening is blocked. Most of the incoming air is therefore forced through the circulation passageways provided in the stacking pattern. Figure 5-B illustrates the path of this movement when the load was under ventilation. This modification would also eliminate the possibility of rain damage at the front of the load.

Refrigeration Service

Several factors influence the efficiency of product refrigeration in trailers. Adequate capacity in the refrigeration unit does not in itself assure effective cooling of the product. Provisions must be made for adequate distribution and circulation of cooled air to the load and for its return to the cooling medium for removal of heat picked up during circulation. These include such features as ceiling ducts, sidewall stripping or ribbing, and floor racks or grooved floors. For non-frozen products from which both vital and sensible heat must be removed during transit, the circulating air must reach the product in order to provide effective cooling. The extent to which this can be accomplished depends upon the adequacy of air circulation channels through the load and upon ventilation openings in the containers to permit access of the cooled air to the product. No one of these provisions, by itself, will assure an effective job of product refrigeration.

The comparative rates of air circulation in refrigerated shipments of oranges in piggyback trailers with open and blocked upper bulkhead screens at

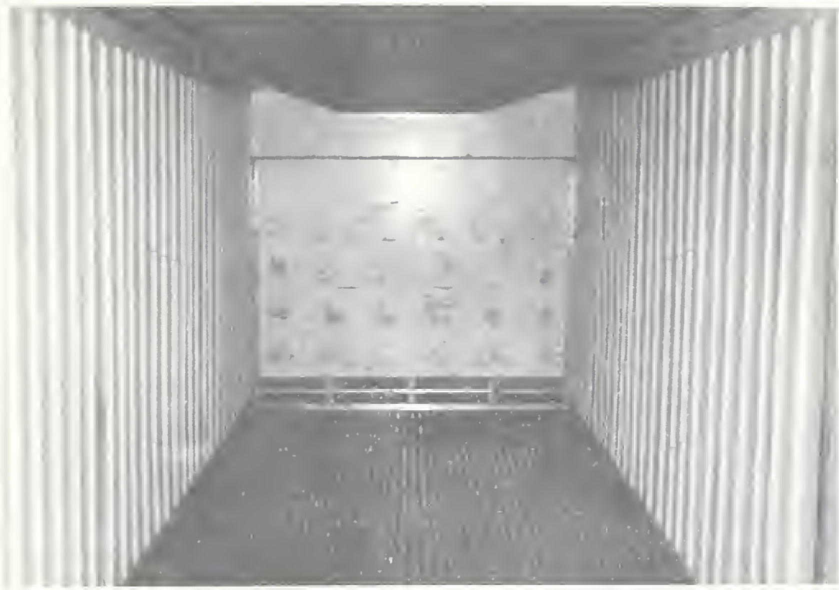

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Figure 7.--Interior of refrigerated piggyback trailer looking toward front of vehicle. The entire screened upper half of the forward bulkhead is covered with plywood. This modification prevents the incoming air in ventilated shipments and the circulating air in refrigerated shipments from short circuiting or bypassing the main body of the load.

different locations in the vehicles are shown in table 2. These data show that in the trailer in which the upper bulkhead screen was left open, the cooled air from the refrigeration unit bypassed most of the load. Most of the cooled air that was discharged through the ceiling duct returned to the refrigeration unit by the path of least resistance, which was over the top of the load to the bulkhead screen. This short circuiting of air over the load made it impossible to realize the full advantage of the capacity of the mechanical refrigeration unit. Air circulation through the channels in the load was negligible. It was also found that considerable air moved down the sidewall openings between the vertical ribbing, which provided perimeter cooling only. The direction of air movement in the sidewall openings, however, was downward in the front half of the vehicle and upward in the rear half.

In the trailer in which the upper screened opening in the bulkhead was blocked, short circuiting of the cooled air through the screen was greatly reduced. Data in table 2 show that air circulation down the sidewall openings was greatly increased by blocking the bulkhead screen. This was especially pronounced in the forward part of the trailer. Air circulation through the boxes at the forward part of the load also was slightly increased. Air movement downward over the rear face of the last stack in the load and forward through the load channels and floor grooves was not greatly improved. This was because most of the cooled air went down the sidewall flues at the forward part of the vehicle.

Table 2.--Comparative air movement in rail piggyback trailer, shipped under refrigeration, by location in trailer and by arrangement of upper bulkhead screen

Location of airflow measurement	Air velocity	
	Screen open	Screen blocked
	Ft/min	Ft/min
From evaporator into ceiling duct	1,500	1,200
Sidewall flues (lengthwise location):		
Rear quarter length	25-40 (up)	75-95 (up)
Half length	70 (down)	20-110 (down)
Front quarter length	70-90 (down)	100-160 (down)
At bulkhead screen	0-70 (down)	450-500 (down)
Through slot at top of boxes:		
Third stack from screen	70	500-700
Down back of load	40-60	50-70
Into channels of load	40-120	80-130
Into floor grooves	50-120	75-150

The refrigeration results produced by this slight improvement in air circulation are shown graphically in figure 8. Although some overall improvement in the rate of product cooling was achieved by blocking the upper bulkhead screen, the difference in cooling rates between the two trailers was not great. The biggest improvement in the cooling rate in the trailer with the modified bulkhead occurred at the half-length position in the vehicle along the sides of the load.

In the trailer with the open bulkhead screen, during a 29-hour period the fruit in 12 cartons in the top layer, rear stack, and sidewall rows showed a range in temperature reduction of 6 to 30 degrees, with an average reduction of 20 degrees F. However, the temperatures of fruit in the center of the load at the half-length of the trailer was reduced only 6 degrees. In the trailer with the upper bulkhead screen blocked, fruit temperature reductions in 12 cartons in the top layer of the rear stack ranged from 16 to 30 degrees, with an average reduction of 25 degrees in a 29-hour period. Temperature of the fruit in the center of the load at the middle half of the trailer was reduced 8 degrees, which was a slight improvement over the load with the unblocked bulkhead screen.

Three factors probably accounted for the failure of the modified bulkhead to produce a significant improvement in the rate of product cooling throughout this type of load, despite the fact that the mechanical refrigeration unit was of ample capacity: (1) Most of the cooled air took the path of least resistance on its return to the refrigeration unit, down the sidewall flues along the forward half of the load, thus bypassing most of the load; (2) the solidly loaded top layer did not permit much of the cooled air discharged from the

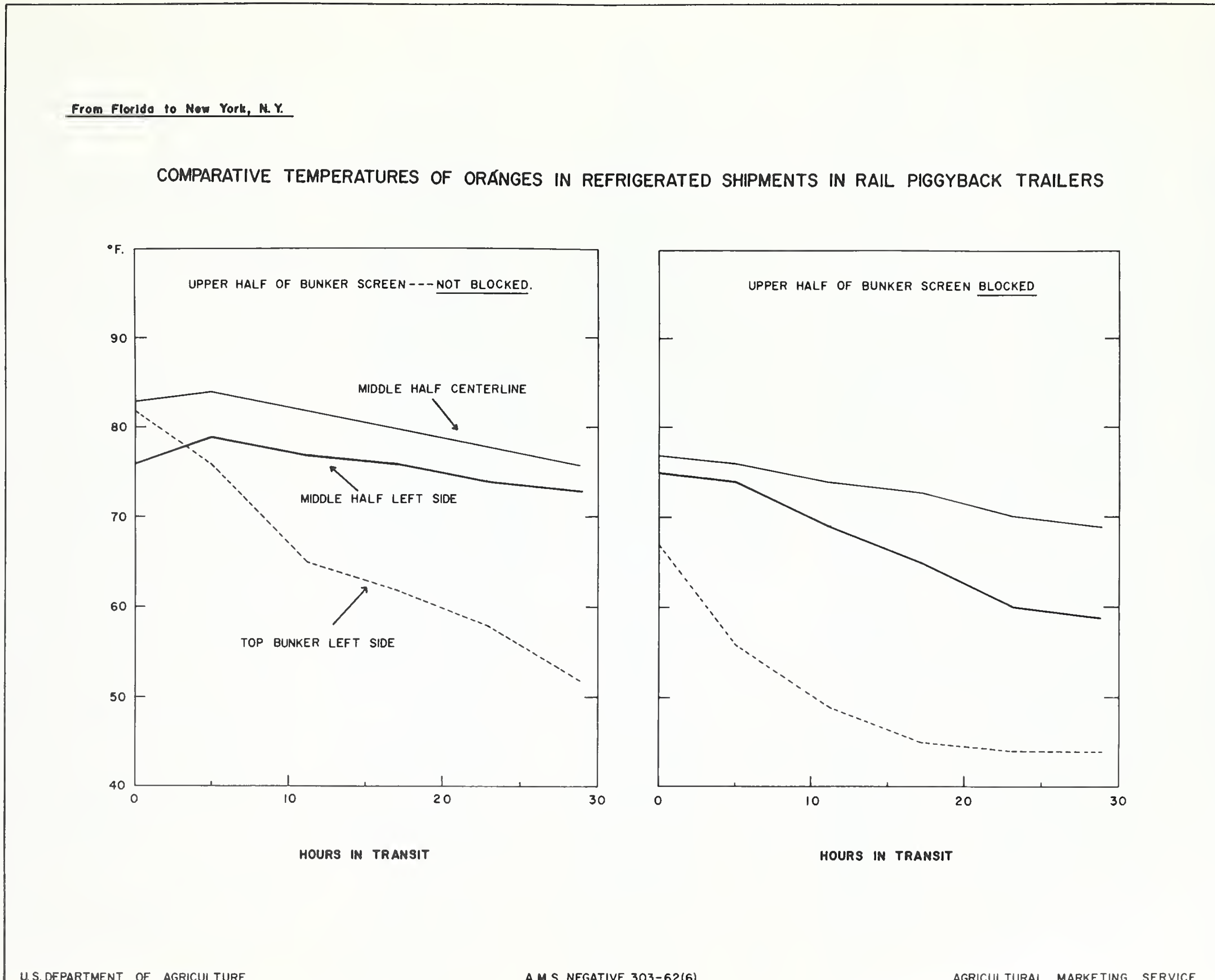
From Florida to New York, N.Y.
COMPARATIVE TEMPERATURES OF ORANGES IN REFRIGERATED SHIPMENTS IN RAIL PIGGYBACK TRAILERS
°F.
UPPER HALF OF BUNKER SCREEN---NOT BLOCKED.
MIDDLE HALF CENTERLINE
MIDDLE HALF LEFT SIDE
TOP BUNKER LEFT SIDE
90
80
70
60
50
40
0
10
20
30
HOURS IN TRANSIT
UPPER HALF OF BUNKER SCREEN BLOCKED
0
10
20
30
HOURS IN TRANSIT
U.S. DEPARTMENT OF AGRICULTURE
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Figure 8.

ceiling duct to enter the main body of the load from the top; and (3) the fruit was packed in full-telescope corrugated fiberboard boxes, most of which had no ventilation openings to provide access of the cooled air to the fruit.

To determine what improvement in cooling rates could be obtained by modifying the top layer of the load in a trailer with the upper bulkhead screen blocked, one test shipment was made in which there were 84 openings between the top layer boxes to permit the cooled air from the ceiling duct to enter the channels in the lower layers of the load. In this shipment the temperature spread throughout the load at destination was only 4 degrees, a considerable improvement over the load previously discussed.

However, because of limited experience with this modified loading pattern, more research with it is required before any conclusions as to its merits can be reached. Further research is needed also to determine what differences in fruit cooling rates can be obtained in the same type of load with the modified bulkhead when boxes with adequate ventilation openings are used, compared to the unventilated boxes.

Quality

Fresh oranges shipped in these tests by rail piggyback service from Florida were delivered in New York on the second morning after departure. All test fruit was delivered and unloaded immediately upon arrival at destination, and little or no decay or rind breakdown was found. No commercial amounts of decay or rind breakdown developed after holding for 7 to 10 days at 70° F.

Other Piggyback Problems

During this study, observations were made of various other problems encountered by shippers and carriers in using this new service for citrus fruit. While some of them may appear to be relatively unimportant in themselves, practical solutions must be applied to them if the full benefit of the new equipment and new service is to be realized. The following are the more important problems and suggested solutions.

1. During the loading of the trailers at the packinghouse, the mechanical refrigeration units were sometimes operated to begin cooling the fruit as it was loaded or for the benefit of the loaders on a hot day. When this was done, the exhaust fumes from the mechanical refrigeration unit frequently were drawn into the trailer through the rear doors and circulated throughout the trailer by the fan on the refrigeration unit. These exhaust fumes can be harmful to employees and may impart some off-flavor to the fruit. Moreover, operating the refrigeration unit with the rear doors open frequently causes the refrigeration coils to become covered with ice which, because of its insulating effect, reduces the cooling efficiency of the unit during the critical period of initial cooling of the fruit after loading has been completed and the doors of the vehicle closed. The refrigeration unit should therefore not be operated during loading. After the trailer is loaded, the unit should not be operated unless all doors are closed.

2. Loaded trailers often remain at the loading dock for several hours before pickup for loading on flatcars. During this time, it is desirable to run the refrigeration unit to cool warm fruit or maintain the low temperature of precooled fruit. However, in many instances it was impossible to close the rear doors on the trailers because the vehicles had been backed tightly against the edge of the loading dock and against the overhanging roof after the rear doors had been opened for loading. For shippers who experience this problem, it is suggested that the trailers be placed about four to five feet from the edge of the loading dock and that the gap between the dock and the trailer be bridged with a long gang board. This makes it possible to close the doors immediately after the fruit has been loaded, to prevent heat pickup by precooled fruit, and to begin cooling the load with the refrigeration unit.

3. Many of the floor drains in the trailers were equipped with U-shaped traps to prevent cold air leakage from the trailer during refrigeration. In many cases, it was noted that these drain hoses had become filled with dirt and debris from previous shipments. If water from top icing were to accumulate on the floor of the trailer, it would be impossible for it to drain out through the hose, and flooding could occur. When shipments under crushed ice are made in these trailers, the drain hoses should be inspected to see if they are open and free of dirt and debris.

4. In general, piggyback trailers receive a relatively smooth ride. However, some sections of rough roadbed may be encountered which may result in considerable vibration of the trailers. This is often true in freight yards. This vibration causes the containers to "creep" from their original positions in the load unless they are effectively tied to their original positions by good loading patterns. Such load disarrangement can result in completely or partly blocking air channels and is a potential source of damage. Crosswise offsetting of the load by loading boxes in alternate layers or stacks in tight contact with the vehicle sidewalls will stabilize the load and help prevent container movement. The rear of the load should also be tightly braced to prevent backward shifting of the containers in the rear stack, which can block the air circulation in this critical area and also can permit slack to develop in the remainder of the load.

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